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REVIEW

Pathological changes produced by surgical dusting powders

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Rubber gloves were introduced into the operating theatres over 100 years ago as part of the new antiseptic technique but also to protect the hands of the surgeon and the nurse from the powerful antiseptic agents then in use *(1)*.

Originally, gloves were sterilised by boiling and then put on wet over the wet hands. With the introduction of dry sterilisation, it was necessary to use a dusting powder to facilitate donning the gloves. The first agents used were lycopodium (the spores of club moss) or talcum powder, which consists chemically of a combination of magnesium silicate (chemically pure talc), together with calcium magnesium carbonate, calcium magnesium silicate and traces of other related substances. It was some time, however, before problems caused by these agents were reported.

Shattock *(2)* recorded the first example of a foreign body talc granuloma in 1917; this was in a patient who developed a granuloma on the lip 11 years after a fall, during which the lip was cut and heavily contaminated with sand. The nodule demonstrated multinuclear cells with giant cell systems around particles of silica and was named by Shattock 'pseudotuberculoma silicoticum'. The first examples of postoperative foreign body granulomas were reported by Antopol *(3)* in 1933 in which granulomas were found to contain spores of lycopodium and, in one case, small refractile bodies that were identical with talc. Three years later, Owen *(4)* described peritoneal nodules which resulted from the use of glove powder containing talcum and by 1943, German *(5)* was able to review 50 instances of talc granuloma after laparotomy. The majority of these were in the omentum and peritoneum, but they were also noted on the ovaries in experimental studies in guinea pigs and rabbits. The same author noted that talc injected into the peritoneal cavity produced granulomas but no adhesions. Adhesions resulted only if, in addition, the peritoneum was traumatised.

In 1947, Roberts *(6)* reported an interesting phenomenon of five women, all of whom had undergone a previous appendicectomy, who were subsequently sterile, all had a low-grade pelvic inflammation and all had thickened fallopian tubes removed at operation. At histological examination, all the specimens showed granulomas which contained talc granules. The talc, deposited in the peritoneal cavity during the original operation appeared to have migrated into the tubes. It is of interest that several of the tubal lesions had previously been diagnosed as tuberculous. By the early 1940s, the dangers of talc were well-recognised and the search was made for substitutes, including calcium carbonate, citrate, phosphate, gluconate and magnesium carbonate. All of these, however, produced adhesions and granulomas when injected intraperitoneally in the rat. Potassium bitartrate was suggested as a suitable glove powder *(7)*. In 1947, Lee and Lehman *(8)* reported the use of corn starch powder treated with epichlorhydrin mixed with 2% magnesium oxide as a desiccating agent as a glove lubricant. This was later marketed as Biosorb® and it is this material that remains in use today. It should be noted, however, that by 1952, one of these authors reported inflammatory reaction and adhesions in the peritoneal cavity of dogs produced by implantation of starch and the risk of any foreign substance within an open wound was emphasised.

It should be noted that although talc has not been used for decades as a glove lubricant, talc granulomas may still occur in operative wounds and within the abdominal cavity. In some cases this may be the result of talc

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contamination of surgical gloves or from talc used by members of the operating team as talcum powder.

The initial hope that the new glove lubricant would prove inert in clinical practice was unfounded. In 1955, two cases of wound granuloma due to starch were reported *(9)*. A year later, McAdams *(10)* reported three patients with granulomatous intraperitoneal foreign body reaction to starch powder.

Paine and Smith *(11)* reported three cases of intraperitoneal starch granuloma in women who had not undergone previous abdominal surgery. In all cases they had had previous vaginal examinations and the authors suggested that the starch had been introduced on the gloves used in this examination which had traversed the genital tract to enter the peritoneal cavity. In this context, Saxen *et al. (12)* described a young woman who had ascites and intraperitoneal granulomas which they traced to the emulsion on the condom that her husband had used. These lesions were reproduced experimentally by injecting the emulsion into a mouse. Another example of pelvic peritoneal starch granuloma was traced to the use of a vaginal douche *(13)* in 1960, Myers *et al. (14)* introduced the term 'granulomatous peritonitis due to starch' in describing three patients who presented with ascites, granulomas and, in one instance, dense adhesions 23–25 days after laparotomy. Starch powder was demonstrated by PAS stain for starch and also by the characteristic refraction properties of starch in polarised light, the so-called 'Maltese crosses'. These authors also demonstrated similar granulomas produced by inoculating glove starch intraperitoneally into rabbits.

Over the next 25 years, numerous reports of starch-induced peritonitis and intraperitoneal granulomas were published from the United Kingdom *(15,16)* the United States *(17–19)*, Europe *(20)*, South Africa *(21)*, Israel *(22)*, Japan *(23)* and Australia *(24)*. These articles varied from single patient reports to series of 20 patients. Most of these appeared in the early 1970s, but sporadic reports have continued to be published since that time *(25)*.

Starch peritonitis is now a well-recognised syndrome *(26)*. At 10 days to 4 weeks after laparotomy, the patient develops abdominal pain, distension, vomiting and a low-grade pyrexia. Examination reveals a distended and tender abdomen. The white cell count is often mildly elevated, to approximately 12 000. A plain radiograph of the abdomen demonstrates distended loops of intestine. Not unnaturally, a diagnosis of intestinal obstruction caused by postoperative adhesions, or intra-abdominal infection, or a combination of both of these, is made. Because of this, the majority of these patients have undergone a second laparotomy, at which time the typical findings are of ascitic fluid (which may be yellow, green or serosanguineous), a thickened nodular omentum, small miliary nodules scattered over the surface of the peritoneum and dense adhesions. If the surgeon is not familiar with this condition, miliary tuberculosis or even carcinomatosis may be diagnosed *(27)*. Examination of a biopsy of one of the nodules examined under polarised light using the frozen section technique will reveal the typical Maltese crosses of starch. Starch granules can also be seen if the ascitic fluid is examined under polarised light. Indeed, if the condition is considered preoperatively, examination of the peritoneal aspirate obtained by fine-needle puncture will reveal starch granules and a diagnosis of starch peritonitis can be made, as was pointed out by Warshaw *(28)*.

Although the majority of studies deal with the intraperitoneal reactions to starch, a number of other syndromes have been noted *(25)*. These include pleural effusion after thoracotomy, pericardial effusion after cardiac surgery, meningism after craniotomy, retroperitoneal fibrosis and starch synovitis after joint surgery.

While there is no doubt that granulomas may form as a tissue response to starch glove powder, two puzzling questions arise from this phenomenon. First, there is the question of why it was only in the 1960s that an apparent epidemic of patient reports of starch granulomas and starch peritonitis began to appear and, second, although it has been shown *(29)* that peritoneal contamination with starch probably occurs with every laparotomy using conventional starch-powdered gloves, the clinical manifestations of reaction to this material are comparatively rare.

An explanation of the first question may be a change in the method of sterilisation of the starch and also of possible talc contamination in the preparation process. An explanation of the second may be the patients who exhibit clinical response to starch may be sensitive to this material.

Initially, starch was sterilised by autoclaving, but this technique was replaced by gamma sterilisation. Capperauld *(30)* demonstrated in the rat model that autoclaved starch is almost totally absorbed from the peritoneal cavity within a period of 48 h. However, irradiated starch was still not fully absorbed after a period of 70 days. Scanning electron microscopic studies on autoclaved starch showed that the surface of the granules was pitted and cracked, while similar studies on irradiated material showed a smooth surface. Capperauld concluded that sterilisation by autoclaving damages the starch in such a way that rapid absorption occurs and a low incidence of granuloma and adhesion formation results. Irradiation does not damage the granule sufficiently to lead to early absorption. An important study by Tolbert and Brown in 1980 *(31)* demonstrated that six of 20 different types of commercial surgical gloves, representing the eight major domestic manufacturers in the United States were found to contain talc at electron microscopic examination. Washing and wiping the gloves showed that talc was more difficult to remove than starch-based powder.

There is evidence that the more florid reactions to starch may be as a result of starch sensitivity. In 1975 Bates *(32)* reported a patient with starch peritonitis in whom a positive skin reaction was demonstrated after an intradermal injection of a glove powder supernatant. In 1973, Holgate *et al. (33)* reported a female patient who had developed starch peritonitis after cholecystectomy. When questioned, the patient admitted to having a skin sensitive to laundry starch. She developed a marked

response to an intradermal injection of Biosorb and, indeed, developed abdominal pain and distension for a period at 48 h after this was done. Findings from a biopsy of the skin lesions showed the presence of a granuloma. Similar intradermal injections into six normal volunteers gave no reaction. Grant *et al. (34)* carried out intradermal starch tests on six patients after starch peritonitis and all showed a brisk skin reaction. In contrast, no reaction was observed in 15 control subjects. This group also carried out an interesting series of studies which demonstrated that delayed hypersensitivity to starch but not to talc could be induced in guinea-pigs inoculated intradermally with starch and Freund's adjuvant. When these immunised animals were challenged with an intraperitoneal injection of starch in saline, florid omental granulomas developed in eight of 36 animals. The rest of the group, together with 36 controls, showed only a low-grade microscopic inflammatory reaction *(35)*.

Although starch is almost universally used as a glove-powder lubricant (the only other being calcium carbonate), other agents are used for products which may have clinical significance. These include condoms, contraceptive diaphragms and dusting powder which comes into contact with the perineum. We have recently studied the effects of such powders in current use in a rat model by injecting saline suspensions of these materials intraperitoneally *(36)*. The substances studied were silica, mica, talc lycopodium, calcium carbonate, magnesium carbonate and Biosorb starch. At present, the choice of dusting agents is determined by factors such as availability and manufacturing convenience as well as user acceptability rather than any pathological effects the powders may produce. All the powders produced adhesions, although Biosorb starch produced the least number of adhesions at all doses compared with the other powders. We were able to rank the powders according to their relative pathological potential from most harmful to least harmful. The silicates, silca, mica and talc ranked highest, followed by lycopodium, calcium carbonate and magnesium carbonate, with starch being the least harmful.

The experimental studies on surgical dusting powders that we and many other investigators have carried out are, of course, somewhat artificial. The important question is what happens when powder contamination occurs at the same time as surgical trauma? After all, the usual state of affairs is that powder contamination takes place at the time of some operative procedure. Many years ago, Jagelman and myself *(29)* showed that an inoculum of 0.1 g of starch was completely absorbed from the peritoneal cavity of the rat within 1 week on macroscopic inspection, but when such a dose was introduced in the presence of peritoneal injury, by removing a 1 cm square of parietal peritoneum, adhesions invariably developed. Also working in my laboratory, Walker *(37)* showed that blood in the peritoneal cavity produced a moderate inflammatory reaction, and bile an intense peritoneal response with total destruction of the peritoneum and underlying muscle. The addition of starch to the blood or to the bile enhanced the intensity of the peritoneal reaction and delayed healing. Recently, we have shown *(38)* that minimal trauma to the peritoneum, by rubbing its surface with six strokes of a piece of gauze, which produces no macroscopic change, in fact desquamates its mesothelium. We are at present investigating the summation of such minimal injury with starch contamination.

Prevention

Obviously there are two ways of preventing the occurrence of starch-powder contamination at operation. The first is to remove all traces of dusting powder and the second the development of a powder-free surgical glove.

We have shown that conventional washing of the donned gloves in saline solution is ineffective. Washing the gloves in two successive bowls of saline fails to remove all the starch and, indeed, results in clumping of the residual starch granules *(29)*. The most effective method of removing starch comprises a 1 min cleansing with povidone iodine followed by a rinse with sterile water *(39)*. This technique, although effective, is time consuming, costly and must be repeated every time the gloves are changed by any member of the surgical team.

In 1982, a surgical glove was produced in which lubrication was effected by a process which bonded a film of Biogel® (hydrogel polymer) to the inner surface of the glove. Biogel is the material used in the manufacture of soft contact lenses and has been determined, in numerous studies, to be entirely non-reactive. The widespread use of Biogel surgical gloves should almost eliminate the hazard of starch contamination in our operating theatres.

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